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MILITARY HANDBOOK

BOILER CONTROLS

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ABSTRACT

Basic design and instrument selection guidance is presented on thermal heating plant instrumentation for use by architects and engineers. Criteria, design and instrument selection requirements are given for the boiler, fuel train and auxiliary equipment.

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FOREWORD

This handbook has been developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other Government agencies, and the private sector. This handbook was prepared using, to the maximum extent feasible, national professional society, association, and institute standards. Deviations from these criteria in the planning, engineering, design, and construction of Naval shore facilities cannot be made without prior approval of NAVFACENGCOM HQ (Code 04).

Design cannot remain static any more than can the functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged and should be furnished to Commanding Officer (Code 111C), Naval Energy and Environmental Support Activity, Port Hueneme, CA 93043.

THIS HANDBOOK SHALL NOT BE USED AS A REFERENCE DOCUMENT FOR PROCUREMENT OF FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE OF FACILITIES ENGINEERING STUDIES AND DESIGN (FINAL PLANS, SPECIFICATIONS, AND COST ESTIMATES). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

MECHANICAL ENGINEERING CRITERIA MANUALS

Criteria Manual	Title	PA
DM-3.01	Plumbing Systems	WESTDIV
MIL-HDBK-1003/2	Incinerators	SOUTHDIV
DM-3.03	Heating, Ventilating, Air Conditioning and Dehumidifying Systems	WESTDIV
DM-3.4	Refrigeration Systems for Cold Storage	WESTDIV
DM-3.5	Compressed Air and Vacuum Systems	WESTDIV
DM-3.6	Central Heating Plants	NEESA
MIL-HDBK-1003/7	Fossil Fuel Power Plants (Proposed)	NEESA
MIL-HDBK-1003/8	Exterior Distribution of Utility Steam, HTW, CHW, Fuel Gas and Compressed Air	CHESDIV
DM-3.09	Elevators, Escalators, Dumbwaiters, Access Lifts, and Pneumatic Tube Systems	WESTDIV
DM-3.10	Noise and Vibration Control for Mechanical Equipment (Tri-Service)	HQTRS
MIL-HDBK-1003/11	Diesel Electric Generating Plants	SOUTHDIV
MIL-HDBK-1003/12	Boiler Controls	NEESA
MIL-HDBK-1003/13	Solar Heating of Buildings and Domestic Hot Water	CESO
DM-3.14	Power Plant Acoustics	ARMY
DM-3.15	Air Pollution Control Systems for Boilers and Incinerators	NEESA
MIL-HDBK-1003/17	Industrial Ventilation Systems	NEESA
DM-3.18	Central Building Automation Systems (Army)	HQTRS
MIL-HDBK-1003/19	Design Procedures for Passive Solar Buildings (Tri-Service)	CESO

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Section 1: INTRODUCTION

1.1 Scope. This military handbook, MIL-HDBK-1003/12, gives criteria for the design of boiler plant instrumentation. Instrumentation is a very fast changing field. The options available in choosing and designing plant instrumentation are numerous. Also a boiler plant includes a large number of instrument items, all of which have to be specified in the procurement of a boiler plant. This handbook does not attempt to cover all details. Rather its purpose is to present general guidelines for selecting and designing instrumentation for boiler plants.

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2.1 General. Most control systems use a combination of different types of controls. Local control loops and final control elements, such as valve and damper operators, are usually pneumatic. Signals from the local control elements to the control board are usually analog electronic. Control room controllers are usually digital.

2.2 Choosing the Type of Control. Choose the type of control that will do the job most economically. This includes total cost over the lifetime of the equipment. Also consider controls used in the existing plant, ease of operation and maintenance, and the types of controls that the plant personnel are familiar with. Consider unique situations such as a high EMF (electric magnetic field) where either EMF shielding or pneumatic controls is required. Do not use obtaining the latest technology as the main criteria in the selection of controls.

The following can be used as guidelines in selecting the type of control. Use microprocessor digital type of control for control panel instrumentation where a large number of control loops are involved. Make all signals to and from the control room electronic. Local controls can be either pneumatic, analog electronic, or digital based on the considerations already discussed above.

2.3 Pneumatic. For standard operating and supply pressures for pneumatic instruments refer to ISA-S7.4, Air Pressures for Pneumatic Controllers, Transmitters and Transmission Systems.

Plant and instrument air is normally available at 90 psig pressure. Instruments normally operate with a 20 psig supply. Standard pneumatic control signal is 3-15 psig. Standard pressures for diaphragm actuators are 15 and 30 psig. Standard pressure for piston operators is 90 psig.

Piston operators are used for dampers and control valves. Use the following design criteria for pneumatic devices operating on 90 psig air. Size them so that they will operate with a 60 psig minimum supply pressure. Use a maximum pressure of 110 psig for design.

For signal transmission of 300 feet and over use 3/8-inch outside diameter (od) copper or stainless steel tubing. For shorter lines use 1/4-inch od copper or stainless steel tubing as a minimum.

The following restrictions apply to the use of pneumatic controllers. Pneumatic control can be used for up to 200 feet without any special provisions and up to 300 feet if the valve has a positioner. If the valve does not have a positioner then for distances between 200 and 300 feet use a volume booster. For distances greater than 300 feet avoid using pneumatic signals for control, instead use electronic signals.

Furnish pneumatic instruments requiring an instrument air supply with individual combination filter-regulators and an output gauge.

2.4 Electronic. Electronic controls can be classified into analog and digital. The main difference between the two is in the type of signal processing and controller logic. For both types of controls the signals between the control devices are usually analog.

2.4.1 Analog. Analog signals include the following:

a) mA direct current (dc) (4-20 mA dc, 10-50 mA dc, or 0-100 mA dc)

b) volts dc (0-10 millivolts dc, 0-100 millivolts dc, or 0-5 volts dc)

c) temperature (thermocouple in millivolts, or RTD)

d) volts alternating current (ac) (120 volts ac)

Of the three milliamp signals the 4-20 mA dc is the more commonly used. For signal requirements for instrument loops refer to ISA-S50.1, Compatibility of Analog Signals for Electronic Industrial Process Instruments.

2.4.2 Digital. The digital part of the controls is usually confined to the control devices such as microprocessor controllers. Incoming and outgoing signals are usually analog, and either electronic or pneumatic. Microprocessor controllers usually include converters which convert the incoming signals from analog to digital and the outgoing signals from digital to analog.

Section 3: GENERAL REQUIREMENTS FOR INSTRUMENTS

3.1 General. Provide control systems in accordance with applicable codes. Refer to para. 3.15 for applicable codes. Design control systems so that the loss of the control medium (air, electricity, or other) will leave the controls in a fail-safe position.

3.2 Instrument Location. Locate instruments on the control room panel as much as practical. Provide local control panels where they are required for start-up of the equipment and where constant attendance is not required. Many instruments, however, have to be mounted locally by necessity. Examples are control valves, orifice plates, and displacer type level instruments.

3.3 Turndown. The instruments have to cover normal operating, turndown as well as upset conditions. Several instruments might have to be provided to cover all of the ranges. It is important that during the plant design stage all instruments be reviewed for covering all of the different operating as well as upset conditions.

3.4 Instrument Ranges. In general use the following criteria in selecting instrument ranges. For flow instruments based on differential pressure have the normal flow at approximately 70 percent of scale. For all other instruments have the normal operating point at 50 percent of scale.

Use the following scales:

a) Flow -- 0-10 square root or 0-100 linear depending on signal

b) Pressure -- Direct reading

c) Temperature -- Direct reading

d) Level -- 0-100 linear

e) Analyzers -- Direct reading

Use suppressed ranges for temperature and pressure as long as they cover startup and upset conditions.

3.5 Alarms and Shutdowns. Design the plant controls to avoid nuisance shutdowns. These can be caused by unnecessary items being interlocked into the shutdowns, bad design, or lack of provisions in case of power or instrument air failure. Also design for easy restart in case of shutdown, especially when caused by non-process type failures such as interruption of power or instrument air.

To alarm or shut down use contacts that open on abnormal conditions. For all shutdowns provide a pre-alarm that precedes the shutdown. Provide separate devices for alarms and shutdowns. Do not use the same device for an alarm or shutdown as used for control. Except for flow, do not operate a shutdown from a transmitter output signal. Have electrical power or instrument air failure shut off all fuel and require attention from operating personnel for a restart.

Include provisions for testing and servicing of the shutdown device and related alarms without interfering with plant operation.

Interlock and other safety requirements for boilers are given in the following American Society of Mechanical Engineers (ASME) and National Fire Protection Association (NFPA) standards:

ASME CSD-1	Controls and Safety Devices for Automatically Fired Boilers
ASME CSD-1a	Addenda to Controls and Safety Devices for Automatically Fired Boilers
NFPA-85A	Prevention of Furnace Explosions in Fuel-Oil and Natural Gas-Fired Single Burner Boiler-Furnaces
NFPA-85B	Prevention of Furnace Explosions in Natural Gas-Fired Multiple Burner Boiler-Furnaces
NFPA-85D	Prevention of Furnace Explosions in Fuel Oil-Fired Multiple Burner Boiler-Furnaces
NFPA-85E	Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces
NFPA-85F	Installation and Operation of Pulverized Fuel Systems
NFPA-85G	Prevention of Furnace Implosions in Multiple Burner Boiler-Furnaces

3.6 Hardware. For hardware standards refer to NEMA-ICS2, Standards for Industrial Control Devices, Controllers and Assemblies.

3.7 Environmental Rating and Enclosures. Provide instruments that are rated for the environment. In addition to enclosure requirements this includes design of the electronic components for temperature and humidity inside of the enclosure, fungus proofing where required, and vibration. Refer to NEMA-ICS 1.1, Safety Guidelines for the Application, Installation, and Maintenance of Solid State Control.

For classification of environmental conditions refer to ISA-S71.01, Environmental Conditions for Process Measurement and Control Systems: Temperature and Humidity, and ISA-S71.04, Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants.

Use enclosures certified by the National Electrical Manufacturers Association (NEMA) for the environment.

Their enclosures are rated as listed below. Refer to NEMA-250, Enclosures for Electrical Equipment (1000 Volts Maximum), and NEMA-ICS 6, Enclosures for Industrial Controls and Systems, for complete specifications including limitations on protection provided.

TYPE	LOCATION	PROTECTION AGAINST OR USE
1	Indoors	Dirt
2	Indoors	Same as above plus splashing water
3	Outdoors	Dust, rain
3R	Outdoors	Rain
3S	Outdoors	Dust, rain, sleet
4	Outdoors	Dust, rain, sleet, hosing down with water or indoors
4X	Outdoors	Same as above plus corrosion resistant or indoors
5	Indoors	Dirt, dust
6	Outdoors	Dust, rain, sleet, hosing down with water, or indoors temporary submersion in water
6P	Outdoors	Same as above plus corrosion resistant or indoors and prolonged submersion in water
7	Indoors	Hazardous locations. Available for Class I, Groups A, B, C, and D
8	Indoors	Same as above except arcing contacts immersed in oil
9	Indoors	Hazardous locations. Available for Class II, Groups E and G
10	Indoors	Hazardous locations. Nonventilated. Meets Mine Safety and Health Administration requirements
11	Indoors	Dirt, splashing water, corrosion resistant Indoors Dirt, dust, splashing water, dripping non-corrosive liquids
12K	Indoors	Same as above except with knockouts. No protection at knockouts.
13	Indoors	Dirt, splashing water, oil, or coolant.

For outdoor locations use NEMA 4. In corrosive environments use NEMA 4X. A space heater is required where condensation of moisture is a problem.

Sometimes enclosures are located in hazardous atmospheres. First consider moving the enclosure outside the hazardous area to reduce cost. The National Fire Protection Association (NFPA) has a rating system for hazardous atmospheres that classifies them into class, group, and division. Use only enclosures that are rated for the hazardous atmosphere. Refer to NFPA-70, National Electrical Code for complete requirements.

Classes are as follows:

a) Class I - Gases and Vapors

b) Class II - Combustible Dusts

c) Class III - Easily Ignitable Fibers or Flyings

Classes I and II are applicable to boiler plants; class III is not.

Divisions are as follows:

a) Division 1 - Normally hazardous

b) Division 2 - Not normally hazardous

Division 1 is usually not applicable to boiler plants except for coal handling and fuel storage areas. Division 2 is often applicable.

Groups are as follows:

a) Group A - Acetylene

b) Group B - Hydrogen and other gases of equivalent hazard

c) Group C - Ethylene and other gases and vapors of equivalent hazard

d) Group D - Natural gas, gasoline, other gases and vapors of equivalent hazard

e) Group E - Metal dusts

f) Group F - Coal dust

g) Group G - Agricultural and plastic dusts

Groups A, B, C, E, and G are not applicable to boiler plants. Groups D and F are applicable.

When specifying enclosures note the following:

Class I, Group D, Division 2 can be met by either providing an explosion proof enclosure or by providing a non-explosion proof enclosure and purging it with air. The non-explosion proof enclosure is less expensive but requires an air supply and more attention in that a constant air purge has to be maintained. Therefore, to keep maintenance to a minimum specify the enclosure as explosion proof for Class I, Group D rather than stating that the enclosure has to be suitable for a Class I, Group D, Division 2 location.

When specifying explosion-proof enclosures include Group requirement. For example, specify the enclosure as Class I, Group D explosion-proof, not just explosion-proof.

An explosion proof enclosure is not necessarily dust tight or suited for an outdoor location. Therefore note both the explosion proof requirement and the weather or dust tight requirement when specifying an enclosure.

For recommended practices on installation of instruments in hazardous locations refer to ISA-RP12.1, Electrical Instruments in Hazardous Atmospheres, and ISA-S12.11, Electrical Instruments in Hazardous Dust Locations.

3.8 Power Supplies. Furnish a power supply for the instruments to provide clean power free of disturbances and nuisance shutdowns. The manufacturer should be able to provide their parameters for clean power and recommend safeguards against severe power disturbances. Refer to ICS 1.1. Include the following:

a) Provide power supplies so that the controls, including combustion safeguard systems and other control devices, operate through an electric power interruption of 20 milliseconds without affecting the operation of the plant.

b) Provide an uninterruptible power supply (UPS) system to keep the electronic instrumentation on line in case of a power interruption. Time to be used depends on the plant and instrumentation, but 30 minutes is often specified. The UPS system has to provide for a safe plant shutdown in case of a longer power outage.

c) Connect all trip circuits to the UPS system.

For UPS system standards refer to NEMA-PE 1, Uninterruptible Power Systems.

3.9 Instrument Air. Provide clean, dry instrument air. Refer to ISA-S7.3, Quality Standard for Instrument Air. Provide instrument air control circuits free of leaks. Refer to ISA-RP7.1, Pneumatic Control Circuit Pressure Test.

3.10 Wiring and Conduits. Have wiring conform to NFPA 70. Run signal, thermocouple, and power wiring in separate conduits. Wiring for alarm, shutdown, and interlock circuits of the same voltage as the power wiring can be run in the same conduit as the power wiring.

For cable and thermocouple wire standards refer to NEMA-WC55, Instrumentation Cables and Thermocouple Wire.

Provide high point vents and low point drains for all conduits.

For recommended practices for control centers refer to ISA-RP60.8, Electrical Guide for Control Centers.

3.11 Instrument Tubing and Piping. Do not bring into the control room, or into control panels or control boards, lines containing process fluids such as water and steam.

Keep pneumatic signals in and out of the control room to a minimum. Use electronic signals instead.

Avoid pneumatic signals in controlled pressure sensitive areas. Certain pneumatic local instruments "bleed" air to its environment.

For recommended practices for control centers refer to ISA-RP60.9, Piping for Control Centers.

3.12 Identification. Identify all instruments and controls with a stainless steel metal tag permanently mounted on the instrument. Include instrument number and service in the identification.

Provide nameplates for all panel instruments on both the front and the rear of the panel. For front of panel as a minimum include instrument number, service, scale factors, and units. For rear of panel only the instrument number is required. For recommended practices on panel nameplates refer to ISA-RP60.6, Nameplates, Labels and Tags for Control Centers.

Identify each electrical and tubing terminal with the instrument item number to which it connects. Tag and number all terminals and the ends of all wires. Identify all electrical conduits as to type of wiring (power, thermocouple, dc signals, or other).

Identify all local instruments such as valves and switches with the item number of the instrument with which it operates.

3.13 Instrument Specifications and Forms. Use instrument specification forms and checklists when ordering instruments. Forms for a number of instruments are given in ISA-S20, Specification Forms for Process Measurement and Control Instruments, Primary Elements and Control Valves. Obtain complete information on the instrument from the manufacturer before ordering. Sources of information include manufacturers catalogs, data sheets and other literature. Provide all data required for ordering the instrument. Specify all items including optional selections and deviations from the manufacturers standard.

3.14 Drawings. Use standard symbols. For standard symbols, presentation, and terminology refer to the following industry standards:

a) ISA-S5.1, Instrumentation Symbols and Identification.

b) ISA-S5.3, Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic and Computer Systems.

c) ISA-S5.4, Instrument Loop Diagrams.

3.15 Code Requirements. The following codes apply:

a) ASME Boiler and Pressure Vessel Code, Rules for Construction of Power Boilers, Section I.

b) ANSI B16.5, Pipe Flanges and Flanged Fittings.

c) ASME B31.1, ASME Code for Pressure Piping Power Piping.

d) DM-3.6, Central Heating Plants.

e) NFPA-70.

f) NFPA-85A.

g) NFPA-85B.

h) NFPA-85D.

i) NFPA-85E.

j) NFPA-85F.

k) NFPA-85G.

3.16 Standardization. Standardize all instrumentation in the boiler plant as much as practical. Have all instruments of the same kind, such as all control valves, from the same manufacturer. Avoid having two control valves in identical service from two different manufacturers or from the same manufacturer but of two different model numbers.

There is no need to buy all of the boiler plant instrumentation from one manufacturer. Standardize instruments of the same type. For example, controllers can be from one manufacturer, control valves from a second manufacturer, and pressure gauges from a third manufacturer.

Packaged equipment, which is often furnished with instrumentation included, does not always lend to standardization. Buying the package manufacturers standard might result in considerable cost savings. Even with packaged equipment, however, the instruments should conform to the plant standards whenever practical.

Also standardize the following for the boiler plant:

a) Use standard signals. They are 4-20 mA dc for analog electronic signals and 3-15 psig for pneumatic signals.

b) Use standard types of connections and connection sizes. Avoid non-standard connections.

c) Standardize on recording charts, recorder pens, lamps and similar items. Note that recorders from two different manufacturers most likely will require different chart paper and pens.

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4.1 General. This section covers instruments usually located on panels. Non-panel instruments, such as control valves, are covered in Section 5.

4.1.1 Types of Control Panels. Boiler plant panels include panels for boiler control, combustion safeguards, and the control of special equipment such as electrostatic precipitators.

4.1.2 Panel Location. Panels can be located either in a control room or locally. Both types of panels are covered in this section and are discussed below.

4.1.2.1 Control Room Panels. Control room is the preferred panel location. Locate as much of the plant instrumentation in the control room as practical. Because of the central location it will simplify both operation and maintenance. Also the control room is usually cleaner, has better temperature and humidity control, and has less vibration than other plant locations. This means less stringent instrument enclosure requirements. Also the instruments will last longer.

4.1.2.2 Local Panels. Local panels are located in the vicinity of the equipment that they control. This can be either indoors or outdoors. The atmosphere can vary from clean to dusty or corrosive. Having a large number of local panels as opposed to centrally located instrumentation means more time and effort required to access and monitor them.

Restrict local panels to instrumentation that do not require continuous attention but are used extensively for start-up and shutdown of the local equipment. Locate the panel as close to the equipment as practical.

Provide a panel designed for the environment. For outdoor locations furnish the panel with a rain hood.

Avoid local wall mounted panels which are mounted flush with the wall. These panels may allow wall condensate to enter.

If the panel is not mounted integrally with the local equipment then make it self-supporting box type.

4.1.3 Layout. Good panel layout requires experienced personnel in both the design of the panel and drawing review by the user. The layout depends on the type of instrumentation to be placed on the panel and how it will be operated. For best results the user and the designer need to both agree what instrumentation will be placed on the various panels and how it will be arranged prior to start of panel fabrication. Once the panel is in fabrication keep changes to a minimum.

For control room panels provide about 10 percent spare panel space for future expansion. Provide 5 to 6 feet clearance between the panel and the wall behind it for access. For recommended practices on control room and panel layout refer to ISA-RP60.3, Human Engineering for Control Centers.

4.1.4 Construction. The following applies to both control room and local panels.

4.1.4.1 Electrical Components. Use solid state logic. Do not use relay logic except where only a few logic steps are involved.

Use items that have a long life and do not have to be frequently replaced. A typical example is the use of neon bulbs instead of incandescent bulbs for indicator lights. The neon bulbs have a longer life.

4.1.4.2 Displays. Use displays that are readily visible to the operator. This might mean specifying LED instead of LCD, although LCD consumes less power.

4.1.4.3 Lighting. Provide lights with on-off switches to illuminate the front of the panel. Also provide lights with switches for inside of the panel enclosure.

4.1.4.4 Steelwork. Fabricate the panel from 11 gauge (0.1196-inch) or 1/8-inch steel plate. Use this thickness for the front, sides, back, top cover, and floor of the panel. Reinforce the plate as required for stiffness. For doors use 16 gauge (0.0598-inch) minimum steel plate. Slightly bevel or round all exposed edges. Larger panels are usually fabricated in 10 to 12 foot long sections. Make the joints vertical. Horizontal panel joints are not acceptable. Use angle iron at each end of a section to make up vertical butt joints. Preassemble the complete panel in the shop to check for accurate alignment and surface matching. Panel joints passing through an instrument are not acceptable.

4.1.4.5 Prefabrication. Specify panels to be complete with all instruments installed, piped, and wired. All that should be necessary to place the panel in service is to connect power, instrument signals, and instrument air supply.

4.2 Individual Item Requirements

4.2.1 Controllers. Boilers use three types of controllers. They are digital (microprocessor or computer based), analog electronic, and pneumatic. Use the following guidelines in selecting the type of controller to be used:

a) Use the type of controller that is the most economical and reliable.

b) For plants with many control loops use digital type of controllers.

c) For plants with few control loops and for local control use either digital, analog electronic, or pneumatic controllers.

d) Avoid use of pneumatic controllers in the control room.

e) For local control consider using pneumatic controllers. This might simplify the controls in that electronic to pneumatic converters are eliminated. Locate local controllers at grade or on a platform where accessible.

f) When using digital control avoid depending on a single or a few control devices for the entire plant without having a backup. If only one loop is controlled by a single controller then a redundant controller might not be required. However, if a large number of loops are controlled by a single controller then provide redundancy so that if the controller fails another controller will automatically take over.

4.2.1.1 Process Controllers. Process controllers use one or several of the following control modes:

a) On-off

b) Proportional

c) Integral (also called reset)

d) Derivative (also called rate)

Most digital controllers have all of the above control modes included. Also they are usually provided with anti-reset windup.

Analog electronic and pneumatic controllers often do not include all three control modes or anti-reset windup.

In general, use the following control modes:

a) Flow -- Use proportional plus reset. Do not use rate action.

b) Level -- Use the proportional mode only where the rate of change of the flow through the line containing the control valve is critical, or where surge capacity of a level controlled vessel is critical. In these two applications use proportional plus reset modes.

c) Pressure and Temperature -- Use proportional plus reset or proportional plus reset plus rate, depending on the application.

For recommended practices on tests to be conducted on digital controllers refer to ISA-RP55.1, Hardware Testing of Digital Process Computers.

When using digital controls, for each control loop provide a separate front of panel control station to include the following:

a) Automatic/manual selection

b) Set point adjustment

c) Output signal adjustment when on manual control

d) Alarm setting

Provide the following alarms:

a) Controller failure

b) High-high alarm

c) High alarm

d) Low alarm

e) Low-low alarm

Provide each control station with the following displays as a minimum:

a) Process reading

b) Set point

c) Output signal

d) Input signal

e) Automatic/Manual indication

f) Controller failure indication

g) High-high alarm

h) High alarm

i) Low alarm

j) Low-low alarm

Provide the following features:

a) Proportional, integral and derivative control modes

b) Anti-reset windup

c) Automatic/manual and manual/automatic bumpless transfer

d) Change configuration without shutting down the control loop

e) Display configuration data without interfering with the operation of the controller.

On controller failure provide the following:

a) If a backup controller is not provided then have the controller switch to manual operation, hold its last output signal, and send out an alarm showing controller failure.

b) If a backup controller is provided then have the control automatically switch over to the backup controller and send out an alarm showing controller failure.

Digital controllers do not always have dedicated contacts for alarms and shutdowns. If the contacts are not provided then specify a controller where dedicated contacts for each alarm and shutdown condition can be easily added using hardware obtainable from the controller manufacturer. Provide SPDT contacts as a minimum.

4.2.1.2 Programmable Logic Controllers. Programmable logic controllers (PLCs) are usually programmed in the electrical ladder diagram format. Other formats are also sometimes used. When specifying PLCs include the following features:

a) Where many logic steps are involved provide a controller that can be programmed in the electrical ladder diagram format.

b) Include provisions so that the controller can be programmed and the program read without disturbing its operation.

4.2.1.3 Controller Configuration. Provide a controller that can be programmed in any of the following ways at the programmers option:

a) From the front of the controller if a separate controller is provided

b) From a manual control station if a separate controller is not provided

c) From a configuration device manually

d) From a configuration device using stored information from a tape, computer disk, or other data storage device

For the controller provide either a non-volatile memory or else battery back-up so that the memory is not lost in case of a power outage. Memory referred here is configuration for a process controller and programmed logic for a PLC.

4.2.2 Recorders. Keep recorders to a minimum. They constitute considerable expense in paper and pen replacement costs. If recorders are required then standardize them so as to keep paper and pen inventory costs to a minimum. Note that recorders from different manufacturers usually require different paper and pens.

Instead of recording data on paper record it on computer disks, tapes or other data storage device. Later the data can be either viewed on a monitor or else printed out or plotted.

4.2.3 Totalizers. Provide a 6-digit minimum totalizer. If the totalizer is reset type, provide a lock to lock out the reset button.

Whenever practical, instead of using a separate totalizer, record the data on a computer disk, tape or other permanent date storage device and use a computer program to add up the totals.

4.2.4 Indicators. Dedicated indicators are commonly used with pneumatic and analog electronic type of control systems.

For digital type of control systems do not specify a dedicated indicator except for critical items. Obtain the information from a control station read-out or from a monitor.

4.2.5 Status Lights. Do not specify a dedicated status light except for critical items. When dedicated status lights are required, use neon rather than incandescent lights as much as practical. Neon lights have lower power consumption and longer life. Use "Push to Test" indicating/status lights to ensure lights are functioning properly.

For digital type of control systems instead of using status lights obtain the information from a control station read-out or from a monitor whenever practical.

4.2.6 Annunciators. For annunciator standards refer to ISA-S18.1, Annunciator Sequences and Specifications. Use common trouble alarms instead of dedicated alarms as much as practical. Provide both visual and audible alarms. For critical items provide a dedicated alarm.

For common trouble alarms provide a dedicated window to which the individual alarms are wired. Also provide a display on a control station, monitor or other device showing which specific item caused the alarm.

For dedicated alarms provide a separate window dedicated to that alarm only.

For annunciator systems include the following items:

a) Solid-state electronic system with first-out sequence.

b) Back-lighted windows.

c) Acknowledge, test, and reset pushbuttons. Locate the pushbuttons outside of the annunciator cabinet so that the cabinet door does not have to be opened to depress the pushbuttons. Provide a separate audible signal device and separate pushbuttons for each annunciator system.

Alarm sequence is by the annunciator manufacturer. A typical sequence as follows:

a) Normal- Light off and audible alarm off

b) Abnormal- Light flashing, audible alarm on

c) Abnormal First Out- Same as above except flashing pattern is different to distinguish it as a first out.

d) Acknowledge- Audible alarm off

e) Other than first-out - Light steady

f) First-out - Light flashing but pattern is different from prior to acknowledgment

g) Return to Normal- Light off and audible alarm off

For annunciator data sheets and checklists refer to ISA-S20, forms S20.2a and S20.2b.

4.2.7 Selector Switches. When using selector switches provide SPDT contacts as a minimum. Clearly label all switch positions. If a position is not used then label it as such. Use back-lighted switches for critical items in areas that are not well lit.

Momentary selector switches may be required for equipment which needs to be electrically sequenced to start on emergency diesel generator power following loss of normal power. This is necessary so as not to overload the emergency power circuit with equipment whose maintained selector switches are in the "Run" mode.

4.2.8 Pushbuttons. Use SPDT contacts as a minimum. For shutdown pushbuttons provide them recessed or covered so as to guard against nuisance trips.

4.2.9 Plant Control Stations. Plant control stations, like panels, can be located either in a main control room or locally. Main control room is the preferred location. Restrict local plant control stations to equipment that require them for start-up or shutdown. In that case locate the control station as close to the equipment as practical.

A typical control station consists of a computer for processing and storing data, a monitor, a keyboard, and a printer. Each of the items is discussed below.

4.2.9.1 Computers. Furnish the computer with a power supply that provides clean power free of disturbances. The manufacturer should be able to provide their parameters for clean power and recommend safeguards against severe power disturbances.

Limit the ability of the computer to control the plant to those functions that can be safely controlled from the computer and in compliance with applicable codes. Provide an alarm connected to an annunciator to show computer malfunction.

If the computer is used for logging data then provide it with an alarm connected to an annunciator to show the following:

a) Data storage capacity is approaching full.

b) Data storage capacity has been exceeded.

If the computer is used for logging of critical data then provide a spare computer to automatically take over if the primary computer malfunctions.

4.2.9.2 Monitors. Monitors most commonly used are the cathode-ray tube (CRT) type. Others include LCD type and luminous gas plasma screen type. If the monitor is used for the display of critical data then provide a spare monitor that can be readily switched over to if the primary monitor malfunctions.

4.2.9.3 Keyboards. Keyboards can be either standard type or non-standard with specialized keys. Use standard keyboards as much as practical. Mistakes are more likely to be made using a non-standard keyboard than using a standard keyboard. Also keyboard replacement is more difficult.

4.2.9.4 Printers and Plotters. For a printer receiving critical on-line data provide an alarm connected to an annunciator to show printer failure. Also provide a back-up printer to take over if the primary printer malfunctions.

4.2.10 Data Logging. For digital type control systems provide the following data logging as a minimum. Print out this information automatically on a dedicated printer:

a) Date, time and device alarmed or shut down

b) Identify first out

c) Time alarm acknowledged

d) Time for return to normal

In date and time include year, day, hours, minutes and seconds. In first out show device to alarm first and device to first shut down the equipment.

4.2.11 Receiver Instruments. These instruments include recorders, indicators, controllers and integrators or totalizers. Each is covered separately in preceding paragraphs. For standard data sheets and checklists for receiver instruments refer to ISA-S20, Forms S20.1a and S20.1b.

4.2.12 Potentiometer Instruments. These instruments include recorders, indicators, controllers and transmitters. Each is covered in a separate paragraph in sections 4 and 5. For standard data sheets and checklists for potentiometer instruments refer to ISA-S20, Forms S20.10a and S20.10b.

5.1 General. This section covers local instruments. Panel instruments are not included. Instruments that are usually located on panels, such as controllers, are covered in Section 4.

5.1.1 Location. Locate the instruments where they are accessible. For instruments that have to be operated during start-up or shutdown of the equipment locate them as close to the equipment as practical. Some instruments have to be accessed continuously for operation, others only during startup and shutdown. All instruments have to be accessible for calibration and maintenance.

Locations of decreasing preference are access from grade, platform, stairs, ladder, and portable ladder.

5.2 Individual Item Requirements

5.2.1 Valves. This paragraph covers control valves, pressure regulators and solenoid valves. Each is discussed below.

5.2.1.1 Control Valves. Common types of flow characteristics for control valves include quick opening, linear, and equal percentage. Select the flow characteristic to suit the application.

For tolerance criteria use ISA-S75.11, Inherent Flow Characteristics and Rangeability of Control Valves.

There are many items to be considered in control valve selection. Check lists are provided in most manufacturers catalogs. For control valve data sheets and checklists refer to ISA-S20, Forms S20.50, S20.51 and S20.52.

Critical items sometimes overlooked include type of shutoff, shutoff pressure, line hydrotest pressure and controllability at turndown conditions. Review all pertinent sizing and selection information including accessories when selecting a control valve.

In general use carbon steel body with stainless steel trim. When required by conditions specify other materials.

As a general rule size the control valve for 30 to 50 percent of the total system pressure drop including the control valve.

Provide manual block and bypass valves around control valves where practical. Refer to ISA-RP75.06, Control Valve Manifold Designs, for guidelines on bypass arrangements. If a manual bypass is not provided then furnish the valve with a handwheel.

Locate control valves at grade where practical. Install the control valve near the operating equipment which has to be observed while on local manual control.

5.2.1.2 Pressure Regulators. Use self-actuated regulators only where operating pressure is below 150 psig and where variations from the control point are acceptable.

5.2.1.3 Solenoid Valves. Common uses for solenoid valves in a boiler plant include control of instrument air to control devices and shutoff service.

Where used to open and close control valves or dampers, check the solenoid valve sizing to ensure that the valve or damper will open or close within the specified amount of time. Port size might have to be increased to ensure the proper actuation time.

When used in shutoff service such as pilot gas check to make sure that the proper solenoid valve is being used for the service. Most manufacturers catalogs include check lists on items to be specified. Critical items sometimes overlooked include type of fluid, shutoff and opening pressures, and line test pressure. For solenoid valve data sheet and checklist refer to ISA-S20, Form S20.55.

5.2.2 Actuators. Use spring-loaded diaphragm type actuators where practical. Use springless operators and cylinder operators only when spring-loaded diaphragm type actuators cannot do the job.

Select the actuator so that the valve or damper, as applicable, will fail safe, that is either lock in position or take a position (either open or closed) that will result in the least upset.

Where a positioner is not provided, furnish a pressure gauge to show diaphragm loading pressure.

5.2.2.1 Positioners. Furnish positioners for all automatically operated dampers. Furnish positioners for all control valves in critical service and where the variable, such as flow, has to be closely controlled. Have the positioner furnished with the control valve or damper, as applicable, not bought separately.

For all positioners provide bypass switches and 3 pressure gauges. The 3 pressure gauges are air supply pressure, instrument loading, and diaphragm pressure.

5.2.3 Current to Pneumatic Converters. Control valves and dampers require current to pneumatic converters (I/Ps) whenever the control signal is electronic and the actuator is pneumatic. It is important that the I/P be matched to the valve or damper, as applicable. To avoid possible mismatch have the I/P furnished with the valve or damper, not bought separately.

5.2.4 Dampers. Dampers can be operated either manually or by means of an actuator. This paragraph covers only actuator-operated dampers. Manually operated dampers are not included in this handbook.

When selecting dampers specify temperature, pressure, pressure drop, type of shutoff, materials, damper bearings, linkages, damper bearing and linkage lubrication, and other data.

For all dampers provide a handwheel or lever so that the damper can be manually operated in case of damper actuator failure.

5.2.5 Pressure Relief Valves. Provide pressure relief valves in accordance with the applicable codes. For pressure relief valve data sheet and checklist refer to ISA-S20, Form S20.53.

5.2.6 Rupture Disks. In corrosive services use reverse buckling type rupture disks at the inlet of the relief valve. For rupture disc data sheet and checklist refer to ISA-S20, Form S20.54.

5.2.7 Level. Provide level instruments in accordance with applicable codes. In general, provide separate vessel connections for each level instrument.

Provide 1/2-inch minimum vent and drain valves with plugs for all level instruments.

5.2.7.1 Gauge Glasses. Complete coverage of total liquid range is not always required. Consult applicable codes. Also consider all operating conditions and upsets. Provide gauge glasses to cover and overlap a minimum of 2 inches beyond the ranges of displacers and switches.

Where ranges are covered by differential pressure type level transmitters, only the critical zone, such as high, low, and normal levels need to be covered by gauge glasses.

Provide illuminators for transparent gauge glasses.

For gauge glass and cock data sheet and checklist, refer to ISA-S20, Form S20.28.

5.2.7.2 Displacer Type Level Instruments. Displacer type level instruments can be used for level ranges up to 60 inches. Avoid use of internal displacers except for open tanks and sumps. As a minimum provide carbon steel body material with stainless steel trim. For displacer data sheet and check list refer to ISA-S20, Form S20.26.

5.2.7.3 Differential Pressure Type Level Instruments. Use differential pressure type level instruments instead of displacer type level instruments for ranges over 60 inches. They can also be used for ranges under 60 inches.

5.2.7.4 Capacitance Type Level Instruments. Avoid the use of capacitance type level instruments in boiler plants. If used, refer to data sheet and checklist in ISA-S20, Form S20.27.

5.2.8 Flow. The most commonly used flow element in boiler plants is the orifice plate. There are numerous other flow measuring devices that can be used depending on the application. In alphabetical order these include coriolis-type mass flow meters, elbow meters, flow nozzles, magnetic flow meters, pitot tubes, pitot-venturi tubes, positive displacement meters, rotameters, target meters, thermal-loss meters (also known as heat-loss meters), turbine meters, ultrasonic flow meters, venturi tubes, vortex flow meters, and wedge elements.

For most flow measurement applications use an orifice plate unless a different type of flow element, such as a flow nozzle or a pitot tube, offers specific advantages. Reasons for using flow elements other than orifice plates include higher accuracy, shorter meter run, lower pressure drop and large line size.

5.2.8.1 Meter Runs. Flow disturbances as much as 100 pipe diameters upstream of the flow measuring element can affect the accuracy of the flow measurement. Meter run requirements including pressure tap locations depend on a number of items. These include type of flow element, beta ratio, and flow disturbances upstream and downstream of the flow element. Flow disturbances include valves, elbows, enlargers, reducers and other pipe fittings. Refer to The Foxboro Company publication, Principles and Practice of Flow Meter Engineering.

For accurate measurements obtain complete meter run requirements from the flow measuring device manufacturer. This includes pressure tap locations and other details such as pressure tap size.

Avoid the use of straightening vanes. Use them only when meter runs without them are not practical.

Do not fabricate meter runs in the field. Fabricate them in a shop qualified in that type of work. Include in the shop fabricated meter run at least 10 pipe diameters of upstream piping and 5 pipe diameters of down stream piping. Straight runs of piping required in addition to the above can be fabricated in the field.

5.2.8.2 Orifice Plates. Orifice plate types include concentric and eccentric, square edge, quadrant edge, segmental and annular. In general, use concentric, square-edge orifice plates except for the following:

For Reynolds number less than 10,000 (based on pipe diameter) use quadrant edge orifice plates.

Do not use concentric orifice plates for horizontal runs flowing wet steam or gas, liquids containing solids, or liquids containing gas or vapor. All of the above will result in inaccurate measurements.

Water in the wet steam and liquid in the wet gas can cause damming of the liquid. Solids in the liquid can settle out upstream of the orifice plate. As a first solution use a concentric, square-edge orifice plate but locate it in a vertical run with flow in the downward direction. If locating the orifice plate in a horizontal run cannot be avoided then use a segmental or eccentric orifice plate.

For liquids containing gas or vapor as a first solution use a concentric, square-edge orifice plate but locate it in a vertical run with flow in the upward direction. If locating the orifice plate in a horizontal run cannot be avoided then use a segmental or eccentric orifice plate with the opening at the top.

Use 2-inch minimum meter run size. Because of possible plugging do not use an orifice bore diameter of less than 0.5 inch. Do not locate orifices where a liquid is subject to flashing.

Select maximum design flow and meter differential to give a scale reading of approximately 70 percent at normal flow. Use a meter differential of 100 inches of water unless not practical.

Use a beta ratio between 0.25 and 0.70, preferably between 0.4 and 0.6. In no case allow the beta ratio to be less than 0.20. Do not exceed a beta ratio of 0.70 for gases or steam and 0.75 for liquids.

Mount the transmitter near the orifice flanges. Use flange taps whenever practical. They are well suited for pipe sizes of 2 inches and larger. For horizontal lines provide meter taps at the top of the flange for gas service and on the sides of the flange for steam, vapor and liquid service. Mount the meter as follows. Below the orifice taps for liquid and steam service and above the orifice taps for gas service. Provide a separate three valve type manifold for each meter.

Use 304SS material as a minimum for the orifice plate. Provide an identification tab projecting beyond the orifice flange. Show the following information on the tab as a minimum. Actual measured orifice bore, pipe inside diameter, orifice plate material, and orifice plate orientation to flow.

For orifice plate data sheet and checklist refer to ISA-S20, Form S20.21.

5.2.8.3 Flow Nozzles. Use flow nozzles for applications where higher accuracy is required than using orifice plates.

5.2.8.4 Venturi Tubes. Use venturi tubes for applications where higher accuracy, lower pressure drop and shorter meter run are required than using orifice plates or flow nozzles.

5.2.8.5 Elbow Meters. Elbow meters can be used for measuring relative flowrates and where absolute readings are not required. Repeatability is good. An elbow in the regular piping can often be used.

5.2.8.6 Pitot Tubes. Use pitot tubes for large ducts where high accuracy and rangeability are not required and where pressure drops have to be kept low.

5.2.8.7 Rotameters. Rotameters are used for flow measurement in small lines such as fuel oil and purge air. Use glass tube rotameters only for purge air. Otherwise use armored type rotameters.

For recommended practices on rotameters refer to ISA-RP16.1, 2, 3, Terminology, Dimensions and Safety Practices for Indicating Variable Area Meters (Rotameters, Glass Tube, Metal Tube, Extension Type Glass Tube), ISA-RP16.4, Nomenclature and Terminology for Extension Type Variable Area

Meters (Rotameters), and ISA-RP16.5, Installation, Operation, Maintenance Instructions for Glass Tube Variable Area Meters (Rotameters).

For rotameter data sheet and checklist refer to ISA-S20, Form S20.22.

5.2.8.8 Magnetic Flowmeters. For data sheet and checklist refer to ISA-S20, Form S20.23.

5.2.8.9 Positive Displacement Meters. Use positive displacement meters only for high accuracy totalizing where measurement of flow rate is not required. Furnish a removable strainer installed upstream of the displacement meter. For positive displacement meter data sheet and checklist refer to ISA-S20, Form S20.25.

5.2.8.10 Turbine Meters. Refer to ISA-RP31.1, Specification, Installation, and Calibration of Turbine Flowmeters. For turbine flowmeter data sheet and checklist refer to ISA-S20, Form S20.24.

5.2.9 Temperature. Temperature instruments include thermocouples, resistance-temperature detectors (RTDs), filled bulb systems, and bimetallic thermometers.

5.2.9.1 Thermowells. Thermowells are used to protect the temperature element from the environment and for personnel protection. Design varies depending on the application. Items affecting design include temperature, pressure, type of fluid and fluid velocity. In general thermowells can be classified into two types--pressure service and non-pressure service. Thermowells used in non-pressure service are commonly referred to as protective tubes.

Provide thermowells for all temperature elements in pressure service. Use 304 SS material as a minimum. For protective tubes use the material best suited for the application.

5.2.9.2 Thermocouples. In general, use the following thermocouples for the different temperature ranges:

a) Type T Copper constantan Below zero to 700 degrees F

b) Type J Iron constantan 0 degrees F to 1,100 degrees F

c) Type K Chromel alumel 600 degrees F to 2,000 degrees F

Thermocouple assemblies can be single (one thermocouple) or duplex (two thermocouples). Provide duplex thermocouples for all temperature control loops. Use one thermocouple for control, the other for indication.

For thermocouple and thermocouple extension wire specifications refer to ANSI-MC96.1, Temperature Measurement Thermocouples, and NEMA-WC55. For thermocouple and thermowell data sheets and checklists refer to ISA-S20, Forms S20.12a and S20.12b.

5.2.9.3 Resistance-Temperature Detectors. Resistance-temperature detectors (RTDs) are used where accurate temperature or temperature difference measurements are required. Use RTDs only where thermocouples will not do the job. For RTD data sheets and checklists refer to ISA-S20, Forms S20.13a and S20.13b.

5.2.9.4 Filled Bulb Systems. Filled bulb systems are used for local temperature indicators, recorders and controllers in services where the fluid temperature is below 800 degrees F. Provide armored capillary tubing for all filled bulb systems. Limit capillary length to 50 feet maximum. In all cases provide a thermowell where the filled bulb system is used in pressure service.

For filled bulb system data sheets and checklists refer to ISA-S20, Forms S20.11a and S20.11b.

5.2.9.5 Bimetallic Thermometers. Bimetallic thermometers are mostly dial type thermometers used for local temperature indication. In all cases provide a thermowell where the bimetallic thermometer is used in pressure service. For bimetallic thermometer data sheets and checklists refer to ISA-S20, Forms S20.14a and S20.14b.

5.2.10 Pressure and Differential Pressure. Elements used for pressure measurement include bourdon tubes, bellows and diaphragms. In general bourdon tubes are used for pressures of 15 psig and greater, bellows for pressures to 15 psig and diaphragms for pressures to 5 psig. Use snubbers where pulsation dampening is required.

For pressure instrument data sheets and checklists refer to ISA-S20, Forms S20.40a and S20.40b. For differential pressure data sheets and checklists refer to ISA-S20, Forms S20.20a and S20.20b.

5.2.10.1 Gauges. Provide blowout discs for pressure gauges with pressures greater than 15 psig. For pressures above 1000 psig provide a safety wall between the dial and the bourdon. Provide pigtail siphons for all gauges in steam service. Provide pulsation dampers and diaphragm seals where required by service conditions.

Locate local gauges so that they are visible from the operating area and are readable from grade or a platform.

For pressure gauge data sheets and checklists refer to ISA-S20, Forms S20.41a and S20.41b.

5.2.10.2 Pressure Switches. For pressure switch data sheets and checklists refer to ISA-S20, Forms S20.42a and S20.42b.

5.2.11 Draft. Draft instruments for boilers require careful attention as to range and sizing. Note that for a balanced draft boiler the draft in the furnace is around 0.1 in WC. Too wide an instrument range results in loss of accuracy. Too narrow a range will not cover all operating conditions.

Make sure that the connections and sensing lines are adequately sized for the low negative pressures. Use larger sizes than for lines sensing pressures.

5.2.12 Electronic Transmitters. Electronic transmitters are used to transmit an electronic signal from a local measuring device to a remotely located device such as a panel mounted controller. Typical transmitters include flow, level, pressure and flue gas oxygen. Typical electronic signal is 4-20 mA dc.

Use stainless steel material for all transmitter components in contact with the stream. Provide local indicators for all electronic transmitters. Locate the indicator at the transmitter for non-controlling loops such as signal to an indicator or recorder. For controlling loops, such as signal to a controller, locate the indicator at the controlling device such as diaphragm-operated valve. For blind electronic transmitters provide an integrally mounted junction box with a metal cover and a terminal block so that a plug-in ammeter can be connected up.

5.2.13 Electrical Instrument Switches. Typical applications for electrical instrument switches are alarms and shutdowns. For fail safe operation the contacts open to alarm or shut down. Provide switches that are suited for the environment. For all locations provide switches that are dust tight and vibration proof. For outdoor locations provide NEMA 4 switches for non-corrosive atmospheres and NEMA 4X switches for corrosive atmospheres.

Provide SPDT contacts as a minimum.

5.2.14 Analyzers. Analyzers used in a boiler plant include the following:

a) In-situ

b) Sample diverted to the analyzer and then returned to the stream

c) Same as above except the sample is discharged to the atmosphere or drain

Use in-situ type of analyzers where practical. As a second choice use an analyzer where the sample is diverted to the analyzer and then returned to the stream. Use an analyzer where the sample is discharged to the atmosphere or drain as a last choice.

For sample returned to the stream use bypass around a pump or other relatively constant differential pressure device. Avoid use of bypass around a control valve.

Where practical use a self-calibrating analyzer that provides zero and span in the range in which the analyzer will be operating. Provide automatic calibration at power-up, at manual command, and at preprogrammed intervals.

Avoid using analyzers as a sole means of control. Use them for trim instead. Other applications include alarms. Avoid using analyzers for shutdowns.

When practical obtain the analyzer from the manufacturer completely packaged in a housing, wired, piped and with the sample system installed. Specify the analyzer to be free standing unless it is mounted on the equipment.

5.2.14.1 Oxygen. Oxygen analyzers in a boiler plant are used for flue gas oxygen measurement. Use the analyzer for alarms and trim. Do not use it as the sole instrument for the control of combustion air.

Always use an in-situ type analyzer.

For forced draft type or pressurized boilers probe location is not critical since leakage is flue gas out of the boiler. For balanced draft boilers, however, leakage is tramp air into the boiler and probe location is critical. Locate the oxygen probe so as to keep the effect of tramp air on the oxygen reading at a minimum. This usually means locating the probe as close to the furnace as practical.

5.2.14.2 Carbon Monoxide. Carbon monoxide (CO) analyzers used in a boiler plant are usually in-situ type infrared analyzers that transmit a beam of light across the stack.

Install the CO analyzer in a clean gas stream downstream of the particulate removal system.

Having a CO analyzer permits firing at lower oxygen levels than without it. Minimum air requirement is established by decreasing oxygen in the stack gas until a large increase in the CO reading occurs.

A CO analyzer is also useful in boiler start-up. During start-up monitor the CO analyzer closely for unsafe firing conditions. High CO readings indicate incomplete combustion, which mean potentially unsafe conditions in the furnace.

5.2.14.3 Stack Opacity. Stack opacity analyzers are used in a boiler plant to monitor particulate emissions. Their main use is in coal and heavy oil fired boilers. Stack opacity monitors are not required for gas fired boilers.

5.2.14.4 Conductivity. Conductivity analyzers are used in boiler plants to monitor dissolved solids in the boiler drum. Use a conductivity analyzer for adjusting boiler blowdown. Do not use it as the sole device for boiler blowdown control.

5.2.15 Flame Detectors. Provide the flame detector best suited for the fuel and flame. For gas fired boilers always use an ultraviolet (UV) self-checking flame scanner.

Do not use a flame detector that is activated by hot refractory.

Provide a separate flame detector for each burner. Locate the flame detector so that it will be activated only by its own burner, not by an adjacent burner.

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6.1 Boiler Control Panel Indicators, Recorders and Totalizers. The instrumentation in Table 1 shows minimum recommended requirements for a boiler plant in the 12,500,000 Btu/h or above range refer to the NFPA 85 series. For a boiler plant below 12,500,000 Btu/h, see ASME CSD-1. The indicators, recorders and totalizers can be either dedicated or shared devices. For shared devices selection can be either by means of pushbuttons, a selector switch, or by entering commands on a keyboard.

If a dedicated indicator is not provided then on selection include the following information in the display: name of process variable, instrument number and units.

If a dedicated recorder or totalizer is not provided then store the process data in a storage device such as a computer disk or tape and label it as to process variable, instrument number, date, time and units. Time includes hours, minutes and seconds. Store the data so that it can be retrieved selectively. In selective retrieval as a minimum include name of process variable, instrument number, date and desired time interval. For data to be recorded also include maximum and minimum points and alarms. Provide a dedicated printer or printer/plotter on which the recorded and totalized data can be presented on paper on demand.

An instrumentation item is not applicable if the equipment that it services is not included in the plant. For example, if an air preheater is not provided then an air preheater outlet temperature indicator does not have to be furnished.

Table 1
Boiler Control Panel Indicators, Recorders and Totalizers
(X shows instrumentation item required)

	INDICATOR	RECORDER	TOTALIZER
Levels			
Boiler drum water	X	X	
Flows			
Boiler steam	X	X	X
Boiler feedwater	X	X	X
Combustion air	X	X	
Fuel gas	X	X	X
Fuel oil	X	X	X
Pressures			
Boiler steam drum	X		
Steam outlet header	X	X	
Boiler feedwater	X		
FD fan outlet	X		
Pilot gas	X		
Fuel gas	X		
Fuel oil	X		
Atomizing steam	X		
Draft			
Boiler furnace	X	X	
ID fan inlet	X		
Differential pressures			
Air preheater air	X		
Air preheater flue gas	X		
Temperatures			
Steam			
Steam drum	X		
Superheater inlet	X	X	
Superheater outlet	X	X	
Steam header	X	X	
Feedwater			
Supply header	X	X	
Economizer outlet	X	X	
Fuel oil	X	X	
Combustion air			
Air preheater inlet	X	X	
Air preheater outlet	X	X	
Flue gas	X		
Superheater outlet	X		
Boiler outlet	X		
Economizer outlet	X		
Air preheater inlet	X		
Air preheater outlet	X		
ID fan inlet	X	X	
Flue gas stack	X	X	

Table 1 (continued)
Boiler Control Panel Indicators, Recorders and Totalizers
(X shows instrumentation item required)

	INDICATOR	RECORDER	TOTALIZER
Viscosity			
Fuel oil	X	X	
Flue gas oxygen	X	X	
Stack opacity	X	X	
Current in amps			
ID fan	X		
FD fan	X		

6.2 Boiler Control Panel Alarms and Shutdowns. The instrumentation in Ta le 2 shows minimum recommended requirements for a boiler plant in the 12,500,000 Btu/h and above range refer to the NFPA 85 series. For a boiler plant below 12,500,000 Btu/h refer to ASME CSD-1. Where a dedicated alarm is specified provide a separate window in an annunciator system. Where a dedicated window is not required provide a dedicated common trouble alarm window to which the non-dedicated alarm is wired. Include a first-out to show which device connected to the common trouble alarm tripped first. For shutdowns provide instrumentation to show which device was first to shut the equipment down.

An alarm or shutdown is not applicable if the equipment that it services is not included in the plant. For example, if the boiler is gas fired only, a low fuel oil pressure alarm is not required.

6.3 Boiler Control Panel Controllers. Provide controllers as required for the proper operation of the boiler plant. For a typical boiler plant required controllers include steam header pressure (plant master and boiler master), boiler drum water level (feedwater flow), fuel flow, combustion air flow and boiler furnace draft.

Table 2
Boiler Control Panel Alarms and Shutdowns
(X shows instrumentation item required)

	ALARMS		SHUTDOWNS
	DEDICATED WINDOW REQUIRED	DEDICATED WINDOW NOT REQUIRED	
Levels			
Boiler drum water			
Low	X		
Low-low	X		X
High	X		
High-high	X		X
Flows			
Combustion air			
Low	X		
Low-low		X	X
Pressures			
Boiler feedwater header			
Low	X		
Boiler steam drum			
Low	X		
Low-low		X	
High	X		
High-high		X	X
Steam header			
Low	X		
High	X		
Pilot gas			
Low	X		
Low-low		X	X
High	X		
High-high		X	X
Fuel gas			
Low	X		
Low-low		X	X
High	X		
High-high		X	X
Fuel oil			
Low	X		
Low-low		X	X
High	X		
High-high		X	X
Atomizing steam			
Low	X		
Low-low		X	X
High	X		
High-high		X	X

Table 2 (continued)
Boiler Control Panel Alarms and Shutdowns
(X shows instrumentation item required)

	DEDICATED WINDOW REQUIRED	ALARMS	DEDICATED WINDOW NOT REQUIRED	SHUTDOWNS
Atomizing air				
Low	X			
Low-low			X	X
High	X			
High-high			X	X
Instrument air				
Low			X	
Low-low			X	X
Scanner air				
Low			X	
Boiler furnace				
High	X			
High-high			X	X
Draft				
Boiler furnace				
High	X			
High-high			X	X
Differential pressure				
Atomizing steam to oil				
Low	X			
Low-low			X	X
Temperatures				
Boiler feedwater				
Low			X	
Fuel oil				
Low	X			
Low-low			X	X
High	X			
High-high			X	X
Flue gas				
Economizer outlet				
Low			X	
High			X	
Stack				
High	X			
High-high			X	X
Fan bearings				
High[1]		X		
Boiler water solids				
High			X	

[1]Provide one thermocouple at each bearing

Table 2 (continued)
Boiler Control Panel Alarms and Shutdowns
(X shows instrumentation item required)

	ALARMS		SHUTDOWNS
	DEDICATED WINDOW REQUIRED	DEDICATED WINDOW NOT REQUIRED	
Oxygen			
Low	X		
High	X		
Smoke			
High		X	
Flame scanner failure		X	
Failure to establish flame		X	X
Flame failure		X	X
Burner valves not closed			
Following trip	X		X
Equipment failure			
FD fan		X	X
ID fan		X	X
Oxygen analyzer		X	
Power failure			
Control	X		X
Equipment	X		X
Boiler shutdown			
Automatic	X		X
Manual	X		X

7.1 General. Provide controls in accordance with applicable codes. Refer to para. 3.15 for applicable codes. The codes take precedence over the control requirements shown in this handbook. A typical control loop is shown in Figure 1.

7.2 Air to Fuel Ratio. Furnish controls to automatically provide the proper fuel to air ratio over the entire boiler operating range from maximum turndown to MCR. Provide cross-limited controls between air and fuel. Use full metering controls when practical. If an oxygen analyzer is tied into the control system then use it for trim only. A typical boiler control system for a single fuel is shown in Figure 2.

Configure the controls so that the air to fuel ratio does not have to be manually reset or reprogrammed when switching from one fuel to another or from one combination of fuels to another. For each fuel or combination of fuels provide an 8-point minimum fuel to air characterization curve. Provide controls so that the air to fuel ratio is automatically adjusted to the proper proportions for all of the following:

a) Load change (between minimum firing and MCR)

b) Fuel change (either change in fuels or same fuel but different specifications)

c) Fuel ratio change (more than one fuel firing)

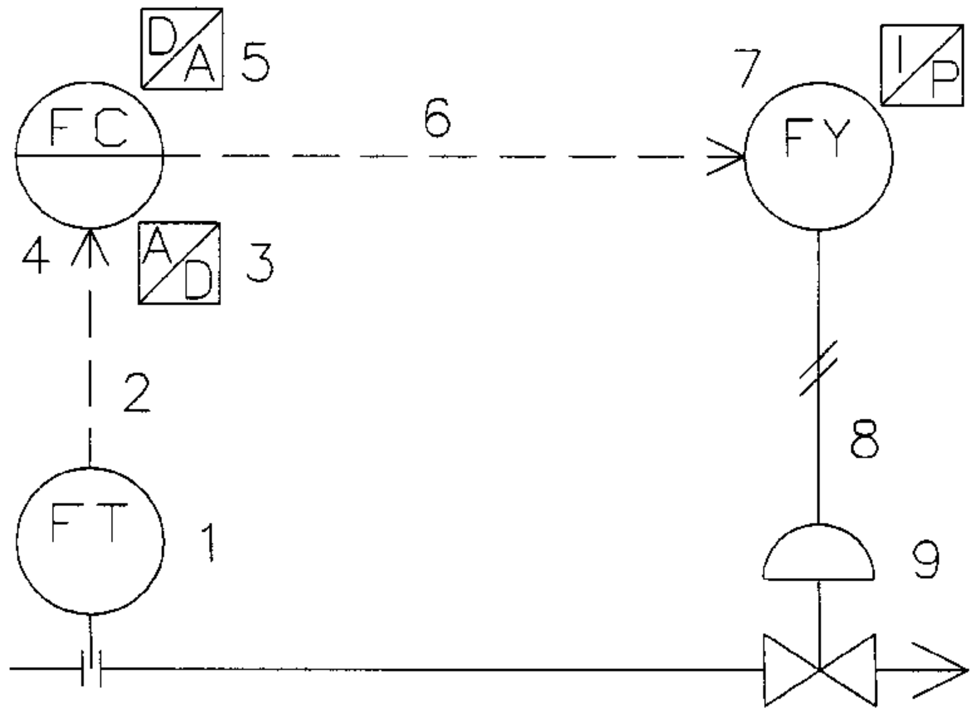
Accomplish the switch over from one fuel to another without shutting down the boiler. Configure the controls so that the changeover from one fuel to another can be made by either a selector switch, pushbuttons, or by entering commands on a keyboard.

For firing several fuels at the same time provide automatic controls for maintaining the proper fuel ratio and fuel to air ratio as the load changes.

Furnish alarms to announce the approach of unsafe conditions. Provide shutdowns to shut the equipment down under unsafe conditions.

7.3 Boiler Drum Level. Provide controls to always maintain the boiler drum level within the boiler manufacturers specifications under all operating conditions. Three types of control systems used in boiler plants are single element, two element and three element. These are shown in Figures 3, 4 and 5 respectively.

Use a single element control system only for boilers operating at steady loads. For boilers operating at variable loads use a three element control system. Do not use two element controls.



LEGEND

1. ANALOG FLOW TRANSMITTER
2. 4–20 MADC ANALOG SIGNAL
3. ANALOG TO DIGITAL CONVERTER
4. DIGITAL FLOW CONTROLLER
5. DIGITAL TO ANALOG CONVERTER
6. 4–20 MADC ANALOG SIGNAL
7. CURRENT TO PNEUMATIC CONVERTER
8. 3–15 PSIG PNEUMATIC SIGNAL
9. PNEUMATIC CONTROL VALVE

Figure 1
Typical Control Loop

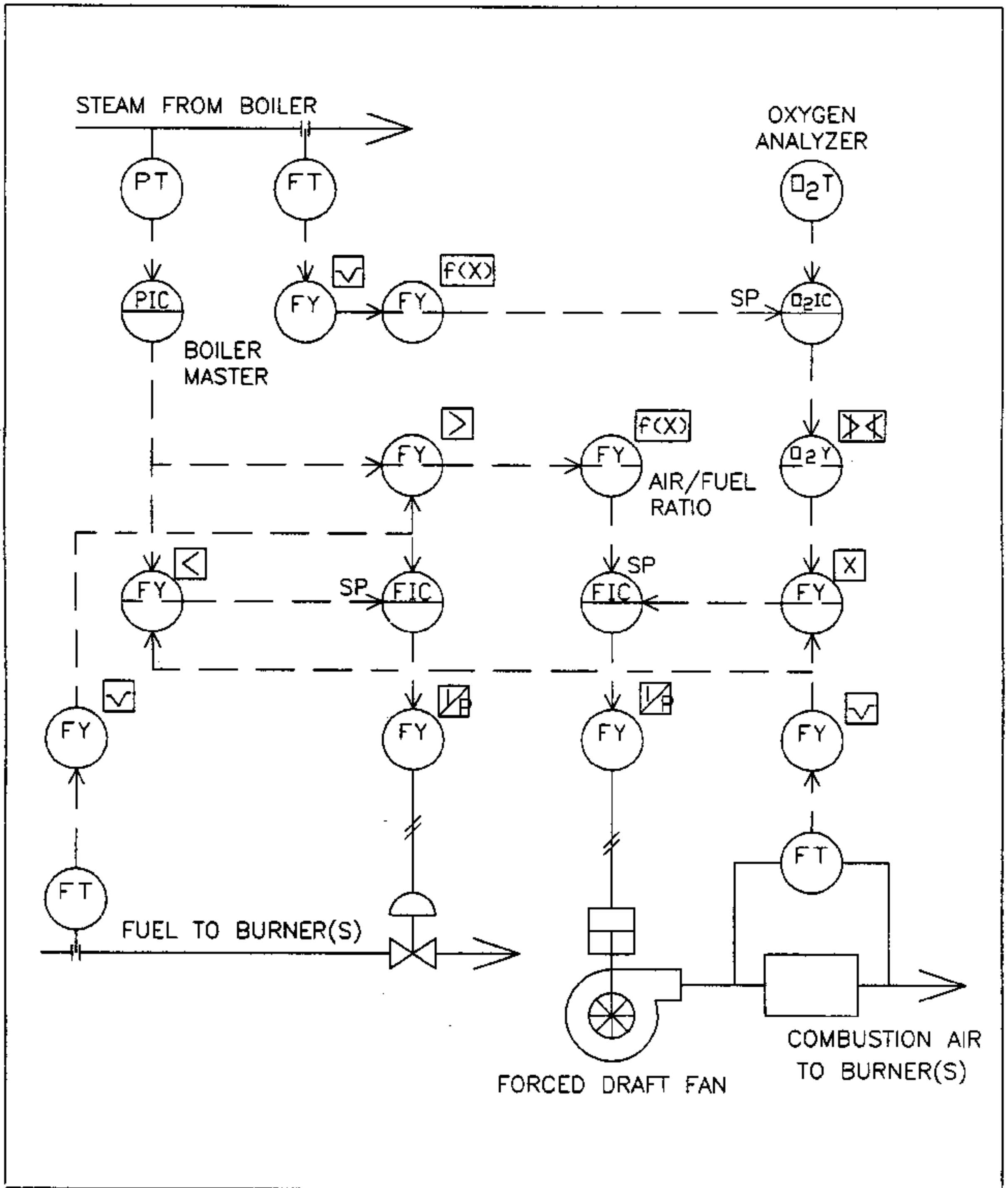


Figure 2
Typical Cross-Limited Boiler Control System for a Single Fuel Using Full Metering

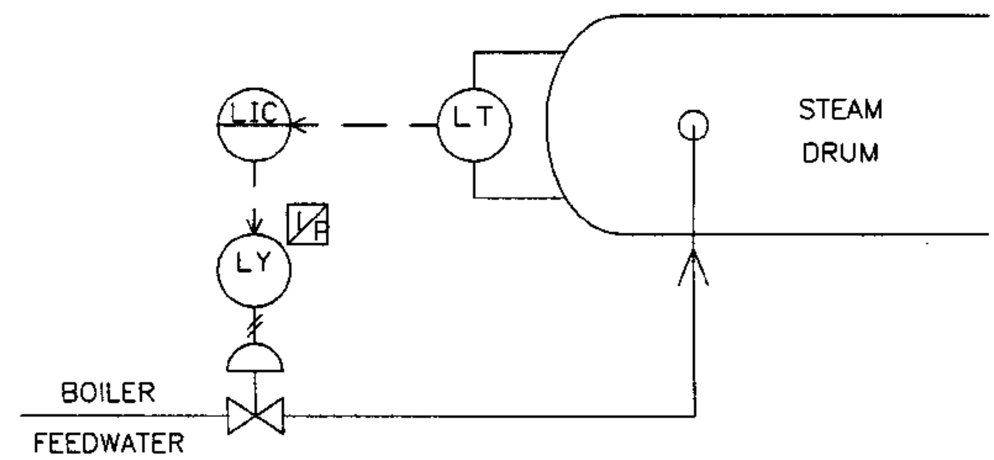


Figure 3
Single Element Drum Level Control System

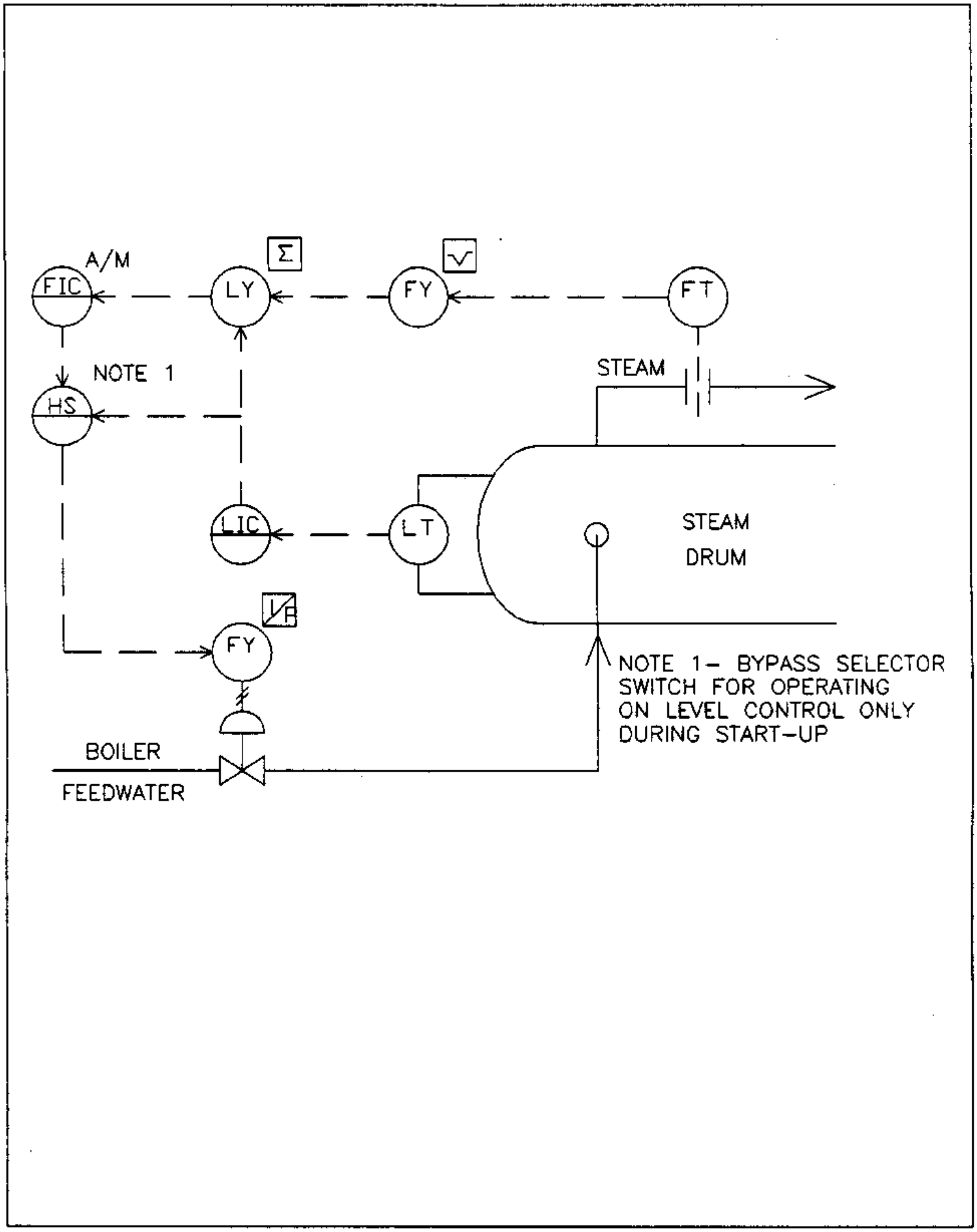


Figure 4
Two Element Drum Level Control System

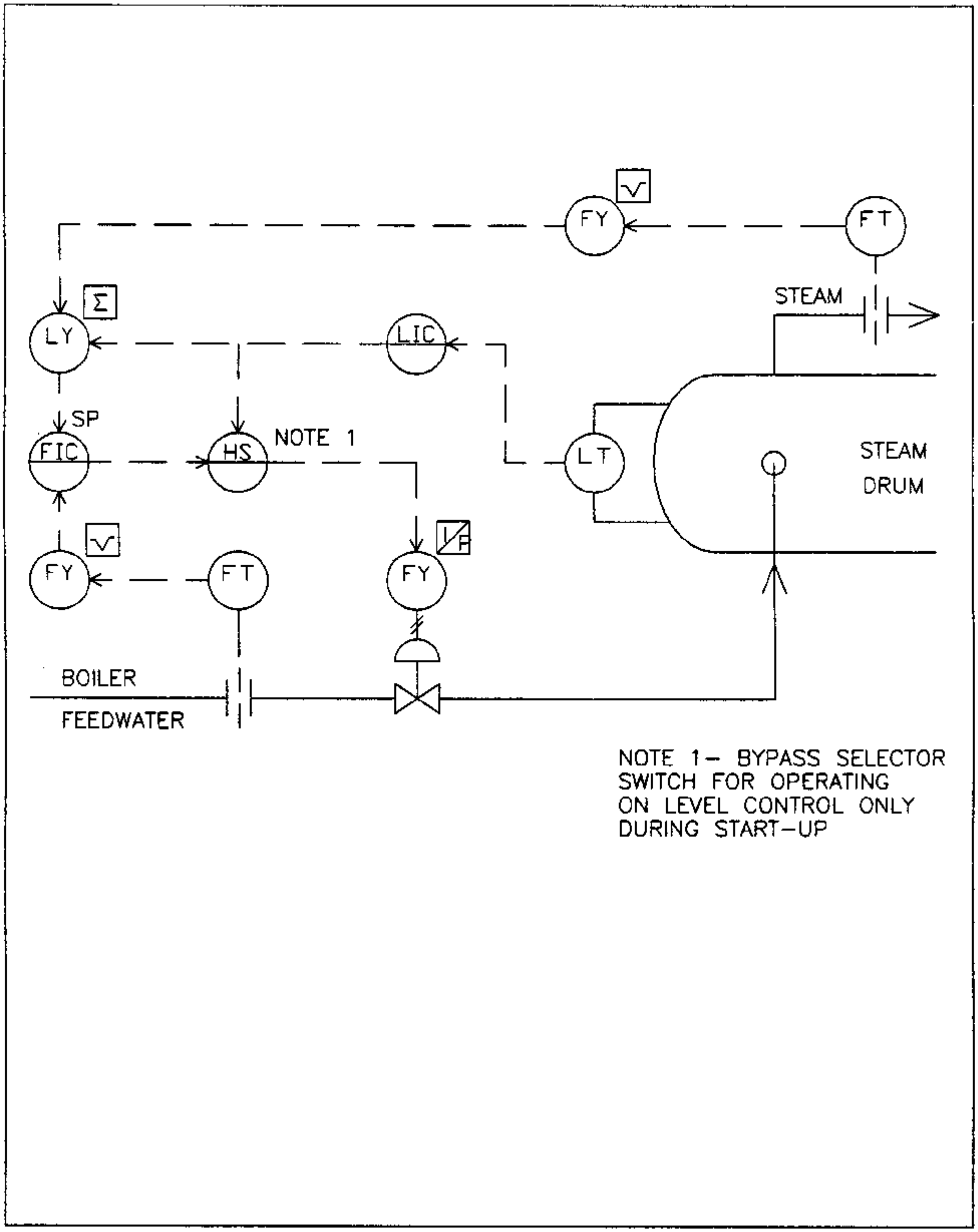


Figure 5
Three Element Drum Level Control System

BIBLIOGRAPHY

Dukelow, S.G., The Control of Boilers, Instrument Society of America, Research Triangle Park, NC, 1986.

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REFERENCES

NOTE: Unless otherwise specified in the text, users of this handbook should utilize the latest revisions of the documents cited herein.

NAVY MANUALS, DRAWINGS, P-PUBLICATIONS, AND MAINTENANCE OPERATING MANUALS:

Available from Commanding Officer, Naval Publications and Forms Center (NPFC), 5801 Tabor Avenue, Philadelphia, PA 19120-5099. To Order these documents: Government agencies must use the Military Standard Requisitioning and Issue Procedure (MILSTRIP); the private sector must write to NPFC, ATTENTION: Cash Sales, Code 1051, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.

DM-3.6 Central Heating Plants

NON-GOVERNMENT PUBLICATIONS:

The following publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the Department of Defense Index of Specification & Standards (DODISS).

Spink, L. K., Principles and Practice of Flow Meter Engineering, available from The Foxboro Company, Foxboro, Massachusetts.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI B16.5 Pipe Flanges and Flanged Fittings (DOD adopted)

ANSI-MC96.1 Temperature Measurement Thermocouples (DOD adopted)

(Unless otherwise indicated, copies are available from American National Standards Institute, 1430 Broadway, New York, NY 10018, Telephone (212) 354-3300).)

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME Boiler and Pressure Vessel Code, Rules for Construction of Power Boilers, Section I

ASME B31.1 ASME Code for Pressure Piping, Power Piping

ASME CSD-1 Controls and Safety Devices for Automatically Fired Boilers

ASME CSD-1a — Addenda to Controls and Safety Devices for Automatically Fired Boilers

(Unless otherwise indicated, copies are available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, telephone (215) 299-5400.)

INSTRUMENT SOCIETY OF AMERICA (ISA)

ISA-S5.1 — Instrumentation Symbols and Identification

ISA-S5.3 — Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic and Computer Systems

ISA-S5.4 — Instrument Loop Diagrams

ISA-RP7.1 — Pneumatic Control Circuit Pressure Test

ISA-S7.3 — Quality Standard for Instrument Air

ISA-S7.4 — Air Pressures for Pneumatic Controllers, Transmitters, and Transmission Systems

ISA-RP12.1 — Electrical Instruments in Hazardous Atmospheres

ISA-S12.11 — Electrical Instruments in Hazardous Dust Locations

ISA-RP16.1,2,3 — Terminology, Dimensions and Safety Practices for Indicating Variable Area Meters (Rotameters, Glass Tube, Metal Tube, Extension Type Glass Tube)

ISA-RP16.4 — Nomenclature and Terminology for Extension Type Variable Area Meters (Rotameters)

ISA-RP16.5 — Installation, Operation, Maintenance Instructions for Glass Tube Variable Area Meters (Rotameters)

ISA-S18.1 — Annunciator Sequences and Specifications

ISA-S20 — Specification Forms for Process Measurement and Control Instruments, Primary Elements and Control Valves

ISA-RP31.1 — Specification, Installation, and Calibration of Turbine Flowmeters

ISA-S50.1 — Compatibility of Analog Signals for Electronic Industrial Process Instruments

ISA-S51.1 — Process Instrumentation Terminology

ISA-RP55.1 — Hardware Testing of Digital Process Computers

ISA-RP60.3 — Human Engineering for Control Centers

ISA-RP60.6	Nameplates, Labels and Tags for Control Centers
ISA-RP60.8	Electrical Guide for Control Centers
ISA-RP60.9	Piping Guide for Control Centers
ISA-S71.01	Environmental Conditions for Process Measurement and Control Systems: Temperature and Humidity
ISA-S71.04	Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants.
ISA-S75.05	Control Valve Terminology
ISA-RP75.06	Control Valve Manifold Designs
ISA-S75.11	Inherent Flow Characteristic and Rangeability of Control Valves
ISA-S77.42	Fossil Fuel Plant Feedwater Control System-Drum Type

(Unless otherwise indicated, copies are available from Instrument Society of America (ISA), P.O. Box 12277, Research Triangle Park, NC 27709.)

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	Enclosures for Electrical Equipment (1000 Volts Maximum)
ICS 1	General Standards for Industrial Control and Systems (DOD adopted)
ICS 1.1	Safety Guidelines for the Application, Installation, and Maintenance of Solid State Control
ICS 2	Standards for Industrial Control Devices, Controllers and Assemblies (DOD adopted)
ICS 6	Enclosures for Industrial Controls and Systems (DOD adopted)
PE 1	Uninterruptible Power Systems
WC 55	Instrumentation Cables and Thermocouple Wire

(Unless otherwise indicated, copies are available from National Electrical Manufacturers Association (NEMA), 2101 L Street, N.W., Washington, DC 20037.)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA-70	National Electrical Code (DOD adopted)
NFPA-85A	Prevention of Furnace Explosions in Fuel-Oil and Natural Gas-Fired Single Burner Boiler-Furnaces
NFPA-85B	Prevention of Furnace Explosions in Natural Gas-Fired Multiple Burner Boiler-Furnaces
NFPA-85D	Prevention of Furnace Explosions in Fuel Oil-Fired Multiple Burner Boiler-Furnaces
NFPA-85E	Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces
NFPA-85F	Installation and Operation of Pulverized Fuel Systems
NFPA-85G	Prevention of Furnace Implosions in Multiple Burner Boiler-Furnaces

(Unless otherwise indicated, copies are available from National Fire Protection Association (NFPA), Batterymarch Park, Quincy, MA 02269.)

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